(12) UK Patent Application (19) GB (11) 2 211 299 (13) A

(43) Date of A publication 28.06.1989

(21) Application No 8824444.7

(22) Date of filing 19.10.1988

(30) Priority data
(31) 877833 (32) 19.10.1987 (33) ZA

(71) Applicant
De Beers Industrial Diamond Division (Proprietary) Ltd

(Incorporated in South Africa)

45 Main Street, Johannesburg, Transvaal, South Africa

(72) Inventors
Barry John Downing
Sean Russell Mercer
John David Salter
Lee Nordin

(74) Agent and/or Address for Service
J A Kemp and Co
14 South Square, Gray's Inn, London, WC1R 5EU, United Kingdom

(51) INT CL⁴
G01N 22/00, B07C 5/344, G01N 15/10

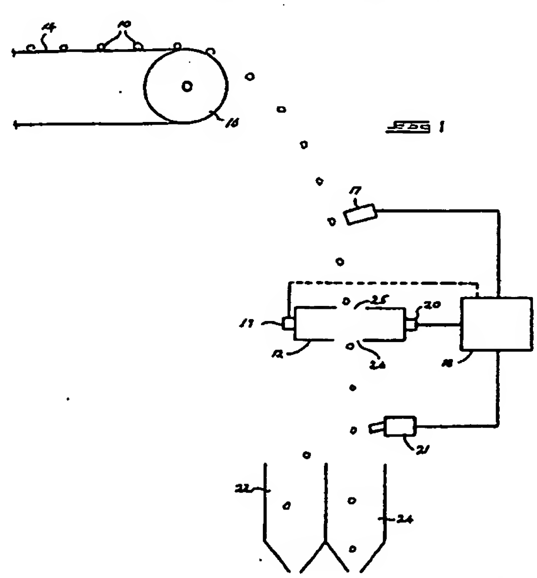
(52) UK CL (Edition J)
G1N N19A3 N19B2A N19C7 N19D1A N19D10 N19F6 N19F7B N19F7C N19H12 N19H7X
U1S S1267 S1279 S1431 S1452 S1488

(56) Documents cited
GB 2188727 A EP 0198670 A2 EP 0176889 A2
EP 0097416 A1 US 3883798 A

(58) Field of search
UK CL (Edition J) G1A AMH, G1N
INT CL⁴ B07C, G01B, G01N

(54) Sorting particulate material on the basis of size or composition

(57) Particles of the mass (10) are passed individually through a resonant cavity (12) in which they are subjected to a swept frequency range of microwave radiation. The spectrum transmitted by the cavity is analysed and compared with a known spectrum and the particles are separated (e.g. at 21) into fractions determined by dielectric constant and/or loss tangent. The system may be used to separate similarly composed particles into fractions on the basis of size differences, or to separate similarly sized particles into fractions on the basis of differences in composition. The cavity may be in the form of chamber (12) through which the particles free fall *via* non-radiating slots (25, 26), the cavity being fed with microwave energy *via* transmission line (19) and which is detected by antenna (20). Alternatively the cavity may be in the form of an open-ended box through which a conveyor belt conveys the particulate material.



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

GB 2 211 299 A

2211299

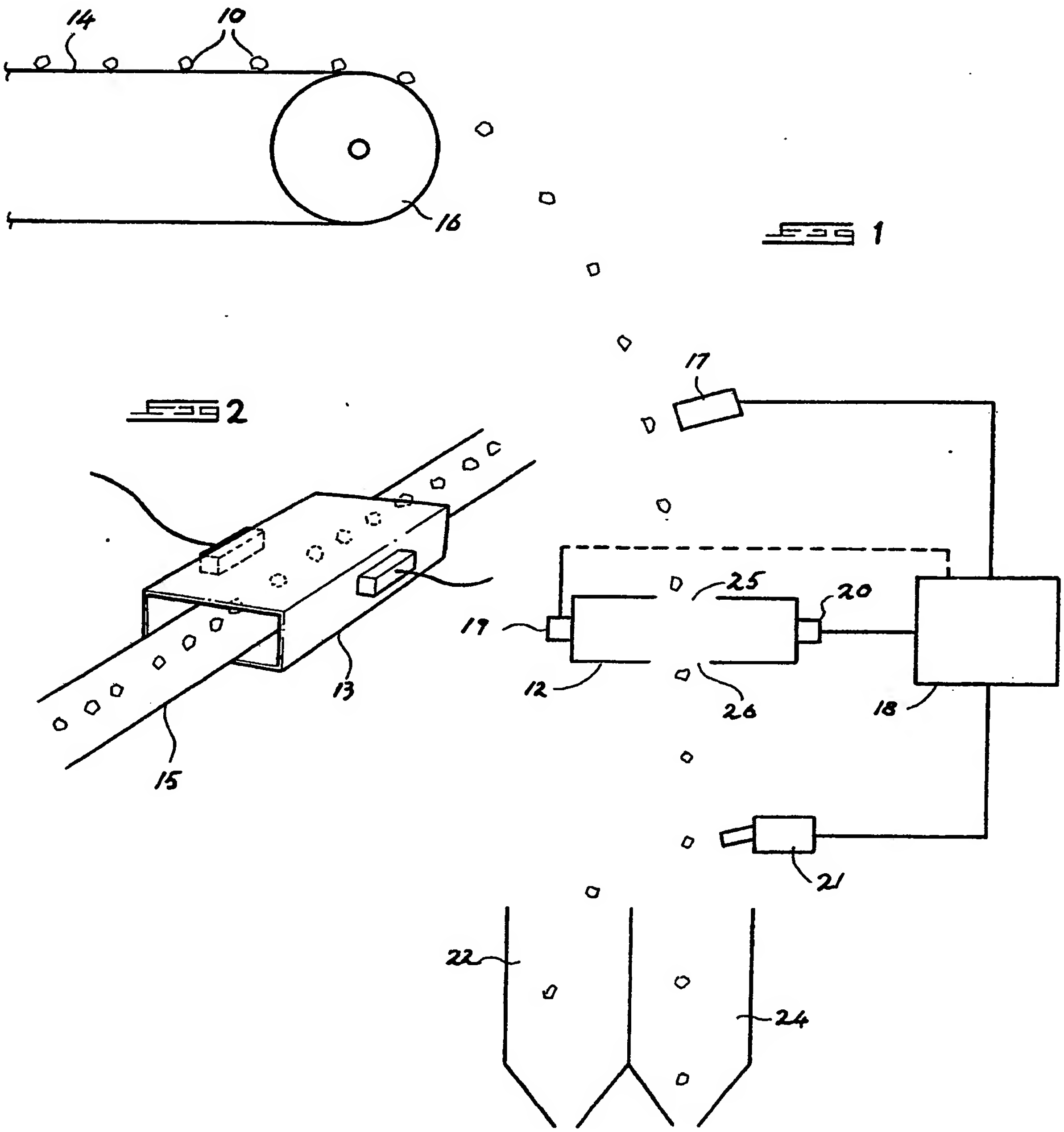


FIG 1

FIG 2

2211299

SORTING PARTICULATE MATERIAL ON THE BASIS OF SIZE OR COMPOSITION

BACKGROUND TO THE INVENTION

This invention relates to an apparatus and method for sorting particulate material.

It is known that a cavity or chamber of predetermined dimensions will have a certain resonant frequency when electromagnetic signals within a specified frequency range are applied to it. If a particle of material enters the space enclosed by the chamber, the presence of the particle in the chamber will result in a change in the resonant frequency and also in the amplitude of the signal transmitted by the chamber at resonance. The change in resonant frequency may be attributed to a change in the dielectric constant of the space as a result of the presence of the particle while the change in amplitude may be attributed to the electrical loss characteristic of the particle. The electrical loss characteristic is referred to in the art as the loss tangent or tan delta.

The present invention proposes to use this phenomenon in a method and apparatus for sorting particulate materials, such as ores.

SUMMARY OF THE INVENTION

The invention provides a method for sorting a mass of particulate material into fractions on the basis of differences in dielectric constant or loss tangent, the method comprising the steps of introducing the particles of the mass into a resonant cavity, applying a swept frequency range of electromagnetic radiation to the cavity while each particle is in the cavity, detecting and analysing the signals transmitted by the cavity, and separating from other particles those particles for which the analysis indicates a certain change in the resonant frequency of the chamber and/or in the amplitude of the transmitted signal at resonance, and therefore the presence of a particle having a predetermined dielectric constant or loss tangent.

In one version of the invention, the method may be used to sort a mass of similarly sized particles into fractions on the basis of differences in composition, while in another version it may be used to sort a mass of differently sized, similarly composed particles into fractions on the basis of size.

The invention also provides an apparatus for use in the method, the apparatus comprising a resonant cavity, means for introducing particles of the mass into the cavity, means for applying a swept frequency range of electromagnetic radiation to the cavity while each particle is in the cavity, means for detecting and analysing the signals transmitted by the cavity, and means for separating from other particles those particles for which the analysis indicates a certain change in the resonant frequency of the chamber and/or in the amplitude of the transmitted signal at resonance, and hence the presence of a particle having a

predetermined dielectric constant or loss tangent.

In one version of the invention, the cavity is in the form of a chamber with upper and lower non-radiating slots through which the individual particles are caused or allowed to fall under gravity. In another version, the cavity is in the form of an open-ended box through which articles are conveyed on a conveyor belt or the like.

It is also preferred that the applied frequencies are in the microwave part of the electromagnetic spectrum.

BRIEF DESCRIPTION OF THE DRAWING

The invention will now be described in more detail by way of example only with reference to the accompanying drawings in which:

Figure 1 illustrates an embodiment of the invention diagrammatically; and

Figure 2 illustrates part of another embodiment.

DESCRIPTION OF AN EMBODIMENT

In Figure 1, a mass of ore particles 10 is organised into a stream and is conveyed on a conveyor 14 passing over a head pulley 16. The ore particles, which are to be sorted into fractions on the basis of relative size or composition, are projected in free fall from the conveyor belt.

In the path of a free falling trajectory of the particles 10 is a resonant cavity in the form of a chamber 12. The particles enter and leave the chamber through non-radiating

slots 25 and 26. Prior to entering the chamber, the free-falling particles pass close to a sensor 17 which detects that a particle is about to enter the chamber and which sends an appropriate signal to a central processor 18 indicative of this fact.

At the appropriate moment, with a particle inside the chamber during its fall from the upper slot 25 to the lower slot 26, the processor 18 energises a microwave generator which applies a pulse or continuous wave of swept frequency microwaves to the chamber via a wave guide antenna or other suitable transmission line structure 19. The signals transmitted by the chamber are detected by an antenna 20 and are fed to the processor 18 which analyses the transmitted spectrum.

The transmission line structure 19, antenna 20 and the chamber itself will be designed for a particular application in accordance with known theoretical principles. The same applies to the non-radiating slots through which the particles enter and leave the chamber.

In the alternative embodiment seen in Figure 2, there is no closed chamber 12. Instead, the resonant cavity in this case is in the form of an open-ended box 13 through which a conveyor belt 15 conveys the particulate material. As in the case of the chamber 12, signals are applied to the box using a suitable trsmission line structure, such as a wave guide antenna, and an antenna is used to detect the transmitted signals which are analysed by a processor.

In one application of the invention, the sorting criterion is particle size. As stated previously, it is known that the presence of a particle in a resonant cavity will result

in a change in the resonant frequency and transmitted signal amplitude to new values as a result of the dielectric constant and loss tangent of the particle (which differs from that of the cavity). Assuming that all the particles have the same composition, the dielectric constant and loss tangent of the space within the chamber 12 or box 13 will be dependent solely on the size of the particle. Thus the change in frequency and amplitude as a result of the particle's presence in the chamber will be dependent solely on the size (i.e. volume) of the particle. In this case, the processor compares the spectrum which is characteristic of the chamber or box alone i.e. without any particle therein, and the detected spectrum. This comparison serves as a basis for a decision by the processor about which fraction the particle should be assigned to.

Note that the comparison may be between the detected spectrum and a known spectrum which is not the resonant spectrum characteristic of the chamber or box alone, but which may be the spectrum which is detected when a particle of known size is in the chamber or box.

In another application of the invention, the sorting criterion is not particle size, but particle composition. In this case, uniformly sized particles are dropped through the chamber 12 or passed through the box 13. In each case, the detected spectrum will be dependent on the dielectric constant or loss tangent of the particle under test, and the processor 18 compares the detected spectrum with a known spectrum to determine whether or not the particle is one having a dielectric constant or loss tangent indicative of a desired composition. As in the previous case, the known spectrum may be the spectrum characteristic of the chamber or box alone i.e. without any particle therein, or that

which is detected when a particle of known composition and hence of known dielectric constant and loss tangent is in the chamber or box.

In order to achieve size consistency, it will be necessary to prescreen the particles. As an alternative to prescreening, the particle size for each particle may be measured before its introduction into the chamber or box and a size correction applied by the processor.

Whichever the basis for the sorting decision, the processor 18 sends a signal to a fluid blast ejector 21 downstream of the chamber 12 or box 13 whenever a desired particle is detected. At the appropriate moment, the fluid blast ejector is actuated to issue a fluid blast which deflects the relevant particle out of the main trajectory and into a desired particle bin 22. Other particles continue unimpeded into the bin 24.

One specific application of the invention, using size variation as the sorting criterion, is in the sorting of density beads which are used to monitor the efficiency of dense medium separation processes, and particularly such processes when used for the concentration of diamond. The beads which are used must be closely sized in order to give good monitoring results and the invention provides a method and means whereby under or oversize particles may be separated from other, properly sized beads.

A specific application of the invention using composition as the sorting criterion is in diamond sorting, where the particles arriving for the sort will be fairly closely sized after passage through the crushers, screens and other mechanical treatment equipment which is conventionally used.

Any substantial variations can be taken into account by size measurements and appropriate correction by the processor. As an example in this specific application, where it was desired to sort diamond particles from kimberlite particles, the chamber was swept with a range of frequencies around a 3GHz centre frequency . With a kimberlite particle, the detected spectrum indicated a resonant peak change in frequency of 120MHz while with a pure diamond particle, the detected spectrum indicated a resonant peak change in frequency of 40MHz. Thus there is a clear distinction forming the basis for sorting pure diamond from kimberlite ore.

It will be noted in this specific example that the change in resonant frequency alone formed a sufficient basis for an accurate sort. In some situations, however, the change in resonant frequency alone may not be sufficient for reliable discrimination between particles to take place. This may, for instance, be the case where the particles being sorted have similar sizes and compositions. In such situations, the change in amplitude in the transmitted signal at resonance will also be taken into account in discriminating between particles. Yet another possibility is for the amplitude change to form the only criterion for the sort.

The invention has also been found to be applicable in the sorting of kimberlite particles from gabbro particles. In experiments conducted using a resonant chamber whose resonant frequency was measured to be 489MHz, kimberlite particles were found to reduce the transmitted signal amplitude by 49% while similarly sized gabbro particles were found to reduce the transmitted signal amplitude by only 5%. The change in transmitted signal amplitude in this case therefore provides a good sorting criterion. Also, the

kimberlite particles were found to induce a frequency shift reduction of 5,2MHz while the gabbro particles were found to induce a reduction of 2,7MHz. Thus frequency change in this case also provides a good sorting criterion.

The results of the kimberlite/gabbro experiments given above were the averaged results from tests carried out with fifty specimens of kimberlite and fifty of gabbro. In each case, the particles were passed through the resonance chamber at a speed of $5ms^{-1}$.

It will be appreciated that the invention is not applicable to ore sorting applications or density bead sorting applications only. In fact, the invention has successfully been employed to sort fruit, such as apples, according to size.

CLAIMS:

1.
A method for sorting a mass of particulate material into fractions on the basis of differences in dielectric constant or loss tangent, the method comprising the steps of introducing the particles of the mass into a resonant cavity, applying a swept frequency range of electromagnetic radiation to the cavity while each particle is in the cavity, detecting and analysing the signals transmitted by the cavity, and separating from other particles those particles for which the analysis indicates a certain change in the resonant frequency of the cavity and/or in the amplitude of the transmitted signal at resonance, and therefore the presence of a particle having a predetermined dielectric constant or loss tangent.

2.
A method according to claim 1 when used to sort a mass of similarly sized particles into fractions on the basis of a difference in composition.

3.
A method according to claim 2 when used to sort diamond particles from kimberlite particles.

4.
A method according to claim 3 wherein the swept frequency range has a centre frequency of around 3GHz.

5.
A method according to claim 2 when used to sort kimberlite particles from gabbro particles.

6.
A method according to claim 1 when used to sort a mass of particles of similar composition into fractions on the basis of differences in size.

7.
A method according to claim 6 when used to sort density beads.

8.
A method according to claim 6 when used to sort fruit.

9.
A method according to any one of the preceding claims comprising the step of comparing the transmitted spectrum with a known spectrum to determine any change in the resonant frequency and/or amplitude.

10.
A method according to claim 9 comprising the step of comparing the transmitted spectrum with the known spectrum of the resonant cavity when there is no particle therein.

11.
A method according to claim 9 comprising the step of comparing the transmitted spectrum with a known spectrum for the resonant cavity with a known particle therein.

12.
A method according to any one of the preceding claims comprising the steps of organising the particles of mass into a stream, causing them to move individually through a resonant cavity and performing a separation of the particles into fractions after they have left the resonant cavity.

13.

A method according to claim 12 wherein the particles are arranged into a stream on a conveyor belt and are projected in free flight from the belt so as to fall individually under gravity through the resonant chamber.

14.

A method according to claim 12 wherein the particles are conveyed,through a resonant cavity in the form of an open-ended box, on a conveyor belt.

15.

A method according to any one of claims 12 to 14 wherein the particles are separated into fractions using a fluid blast ejector.

16.

A method according to any one of the preceding claims wherein the frequency range is in the microwave part of the spectrum.

17.

Apparatus for use in the method of any one of the preceding claims, the apparatus comprising a resonant cavity, means for introducing particles of the mass into the cavity, means for applying a swept frequency range of electromagnetic radiation to the cavity while each particle is in the cavity, means for detecting and analysing the signals transmitted by the cavity, and means for separating from other particles those particles for which the analysis indicates a certain change in the resonant frequency of the cavity and/or in the amplitude of the transmitted signal at resonance, and hence the presence of a particle having a predetermined dielectric constant or loss tangent.

18.
Apparatus according to claim 17 comprising a sensor for detecting particles prior to their introduction into the resonant cavity.

19.
Apparatus according to either one of claims 17 or 18 comprising a conveyor belt on which the particles are transported in a stream and from which the particles are projected in free flight so as to fall under gravity through a resonant chamber, and separation means downstream of the chamber for separating the particles into fractions.

20.
Apparatus according to either one of claims 17 or 18 comprising a resonant cavity in the form of an open-ended box, a conveyor belt for conveying the particles through the open-ended box, and separation means downstream of the box for separating the particles into fractions.

21.
Apparatus according to claim 19 or claim 20 wherein the separation means comprises a fluid blast ejector.

22.
Apparatus according to any one of claims 17 to 19 wherein the resonant chamber has non-radiating slots through which the particles enter and leave the chamber in free flight.

23.
A method for sorting a mass of particulate material into fractions substantially as herein described with reference to the accompanying drawing.

24.
An apparatus for sorting a mass of particulate material into fractions substantially as herein described with reference to the accompanying drawing.

Published 1989 at The Patent Office, State House, 66/71 High Holborn, London WC1R 4TP. Further copies may be obtained from The Patent Office